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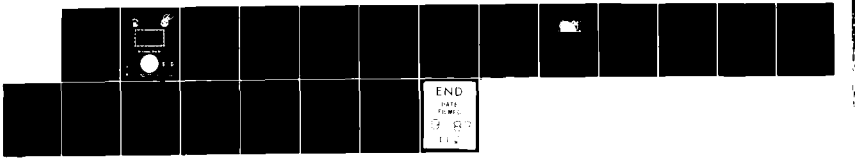

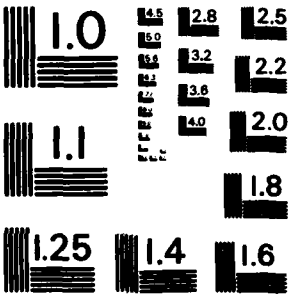

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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 11-83

EVALUATION OF BAUER MARINER "D" HIGH PRESSURE BREATHING AIR COMPRESSOR

STEPHEN F. WARGO

AUGUST 1983

(6)

DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407

IN REPLY REFER TO:

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BAUER MARINER 'D'
diesel driven
air compressor

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

In July 1982, the BAUER MARINER "D" high pressure air compressor was tested by the Navy Experimental Diving Unit in response to reference 1. The purpose of this test was to determine if the equipment was suitable for use by the United States Navy (USN) diving community.

The BAUER MARINER "D" met manufacturer's specifications for quantity of air produced with a quality which met or exceeded purity standards. The design

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The BAUER MARINER 'D' is considered to be suitable for USN requirements for compressors of this size and type.

Table of Contents

Abstract

In July 1982, the BAUER MARINER "D" high pressure air compressor was tested by the Navy Experimental Diving Unit in response to reference 1. The purpose of this test was to determine if the equipment was suitable for use by the United States Navy (USN) diving community.

The BAUER MARINER "D" met manufacturer's specifications for quantity of air produced with a quality which met or exceeded purity standards. The design and engineering was determined to be adequate as no material failures were encountered during testing.

The BAUER MARINER "D" is considered to be suitable for USN requirements for compressors of this size and type.

KEY WORDS: BAUER MARINER 'D', diesel driven, air compressor.

I. INTRODUCTION

In accordance with reference 1, the BAUER MARINER "D" high pressure breathing air compressor was tested by the Navy Experimental Diving Unit (NEDU) to determine if the compressor discharges suitable breathing air and has a service life which satisfies the requirements for portable SCUBA diving compressors throughout the Navy.

Compressor testing simulated the field operation of intermittently filling SCUBA cylinders to 3000 psig. A total of 50 hours of compressor operation as compiled. The testing included subjective evaluation of the systems operation but not detailed mechanical review of individual components of the system.

NEDU has previously evaluated several portable high-pressure air compressors (references 2 through 5). Mechanical failures in the compressor or prime mover, low capacity, or poor quality of breathing air were cited as reasons for nonacceptance of all but one unit. At the time of this report, there are five portable high-pressure air compressors which have been Authorized for Navy Use (ANU); four are gasoline engine driven and one is diesel driven.

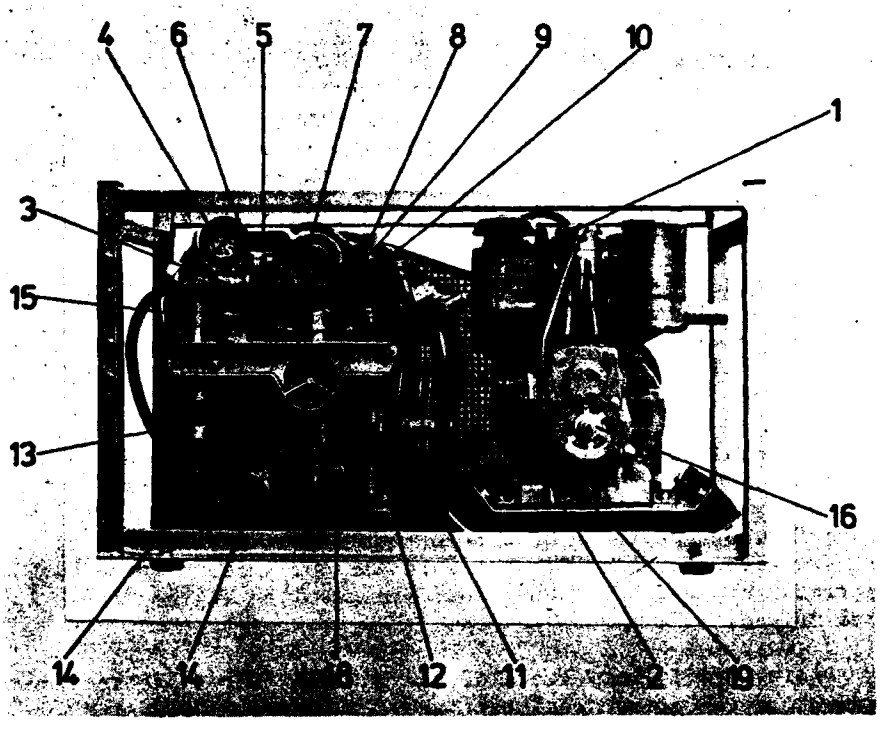
During preliminary tests of the MARINER "D", a problem concerning the alignment of the drive "vee" belt arose. During engine start up, the "vee" belt was thrown off the compressor pulley as the engine attempted to gain and maintain a set throttle speed. The manufacturer requested testing be stopped while the problem was researched and a solution instituted. The BAUER's solution to the problem consisted of replacing the single drive "vee" belt system with one utilizing twin "vee" belts. The engine shock mount was also replaced by one of a stiffer design. This design proved satisfactory and testing was resumed.

II. EQUIPMENT DESCRIPTION

The BAUER MARINER "D" high-pressure breathing air compressor (Figure 1) is one of a line of high-pressure air compressors manufactured by BAUER BREATHING AIR, Inc., 1328 Azalea Garden Road, Norfolk, Virginia 23502. The compressor, serial no. 77109, is a portable three stage, three cylinder, high pressure type designed to deliver 7.0 cubic feet per minute (ACFM) at 3200 psig.

The prime mover is a HATZ model E79 four stroke small cylinder diesel engine. The engine is an air cooled turbulence-chamber, manually started unit. Rotational torque is transferred to the compressor by twin "vee" belts. Filtration was accomplished by two interstage moisture separators and a ANU listed Pall Trinity filter (reference 6) immediately upstream of the charging whip. A back pressure regulator is installed downstream of the Pall Trinity filter to ensure maximum filtration and the required back pressure loading of the valves and floating piston in the third stage.

FIGURE 1



M 4 D, M 4 D-H (M 4 D shown)

Item	Description
1	Motor intake filter
2	Engine-stop lever
3	Filling valve
4	Gauge
5	Oil filler cap
6	Final safety valve
7	Intake filter
8	Pressure maintaining valve
9	Filter head with pressure maintaining valve
10	Union nut
11	Purifier
12	Condensate drain cock
13	Oil and water separator
14	Condensate drain cock
15	Intermediate filter
16	Rope starter
18	Oil drain plug compressor
19	Oil drain plug engine

The compressor lower end and second stage is splash lubricated by an oil thrower pin on the crankshaft. First stage lubrication is accomplished by venting oil mist from the crankcase to the air inlet port. The third stage is force lubricated with a pump driven by an eccentric on the crankshaft and regulated to 725 psig. The compressor requires approximately 1.75 quarts of oil. The manufacturer recommends that only specific oils should be used. These oils are not stocked in the Federal Supply System.

Figure 2 provides a schematic flow diagram of the compressor/filtration system. The filter system described in Figure 2 represents the BAUER filter package. For these tests items 9, 10 and 13 were replaced by the ANU listed Pall Trinity filter which is also available from BAUER upon request. APPENDIX A contains the manufacturers technical specifications for the compressor.

III. TEST PROCEDURE

The compressor was set up in accordance with the manufacturer's instructions. Yellow Springs Instrument temperature probes were attached to measure compressor discharge and ambient air temperature. A safety line was installed on the charging whip. The unit was placed in an exterior open work area with the air intake facing the prevailing wind, upstream of the engine exhaust. The test site was not changed, but the air intake was repositioned as dictated by shifts in wind direction. APPENDIX B contains the complete test plan used and pass/fail criteria used during the evaluation. APPENDIX C contains a sample test log on which data was recorded.

A. Endurance Test. The compressor was operated daily to charge twin 50 cubic foot (cu/ft) SCUBA tanks until 50 hours of operation were logged. The following parameters were recorded:

(1) Start up time.

(2) Relative humidity.

(3) Volume of condensate.

(4) Total hours running time.

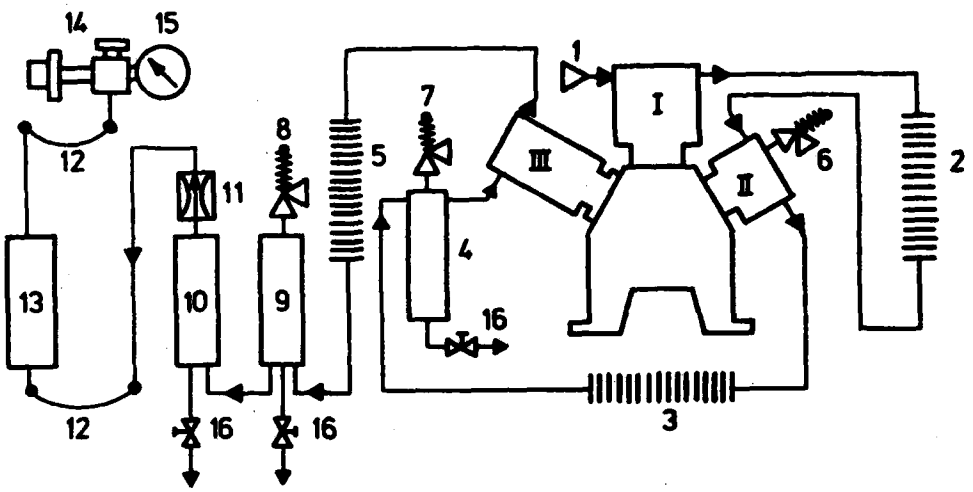
(5) Ambient air temperature.

(6) Compressor discharge air temperature.

B. Charge Rates. The volume of air delivered and the time to achieve that volume was logged for each cycle and the fill rate for maximum, minimum and overall average for the test series was computed.

C. Fuel and Oil Consumption. At the beginning of the test the fuel tank was filled. All fuel added was logged and the fuel tank was refilled and logged at the end of the test. An average hourly consumption for the test was computed. Lubrication oil consumption was monitored during operations and all consumption logged.

FIGURE 2



Air Flow Diagram

Item	Description
1	Micronic Intake Filter
2	Inter-cooler, 1st – 2nd stage
3	Inter-cooler, 2nd - 3rd stage
4	Intermediate filter, 2nd – 3rd stage
5	After-cooler
6	Safety valve, 1st stage , 8 bar
7	Safety valve, 2nd stage, 50 bar
8	Safety valve, 3rd stage , 225 (330) bar
9	Oil and water separator
10	Purifier
11	Pressure maintaining valve
12	Filling hose
13	Drying filter
14	Filling valve
15	Pressure gauge
16	Condensate drain cock

D. Air Sampling. The compressor discharge was sampled at hours 1, 5, 15, 30, 45 and 51 and sent to Texas Research Institute, Inc., 5902 W. Bee Caves Road, Austin, Texas 78746, in accordance with their instructions for air analysis.

E. Maintenance. Scheduled maintenance was performed in accordance with the manufacturer's instructions and consisted of the following:

1. Drain condensates every 15 minutes.

2. Fuel level checked hourly.

3. Lubricant levels were checked prior to start-up each day, following shut-down and approximately every four hours.

IV. RESULTS AND DISCUSSION

A. Endurance Test. The compressor was trial run to ensure proper operation and draw a preliminary air sample. During the 50 hour operating period, the compressor accumulated 217 charging cycles using twin 50 cu/ft SCUBA cylinders.

B. Charge Rates. The test data provided a complete operational and maintenance log for this test and was the basis for computing and evaluating all the test results. Compressor charge rates for the SCUBA air cylinders used during the test were:

	Time	Number of Occurences	Charge Rate
Average:	21,700 cu/ft in 50 hours 25 minutes		7.17 CFM
Maximum:	11 minutes	5 times	9.09 CFM
Minimum:	25 minutes	1 time	4.00 CFM

NOTE: Maximum and minimum charge rates were achieved as a result of operator error. Minimum charge rate was caused by condensate valve leaks. Maximum charge rate was attributed to pressure buildup in charging lines and filter while changing SCUBA bottles. Delays following disconnection of charged SCUBA bottles and reconnection of an empty set of SCUBA bottles allowed a pressure build-up in the compressor charging line of over 3100 psi. Normal operating procedure allows compressor to vent to atmosphere between charging evolutions. There was no increase or degradation of the charging rate during the test.

A 5.8°C temperature differential between ambient temperature and compressor discharge temperature was the maximum recorded. The majority of the temperature differentials were at least 2°C lower. This minor carryover of the heat of compression is not great enough to have a significant effect in the resultant SCUBA bottle temperature.

C. Fuel and Oil Consumption

1. Fuel used: 16 gal, 3 qt, 14 oz.

2. Time run: 51 hours, 47 minutes.

3. Average consumption: 1 qt, 9.7 oz per hour.

During the test the engine consumed 520 milliliters of oil which averages 10 milliliters or 1/3 of a fluid ounce per hour and is considered insignificant.

D. Air Sampling. The results from the air samples are shown in Table 1. All samples were within units established by reference 7.

E. Maintenance. The BAUER MARINER "D" compressor unit was easily maintained and no problems were encountered. The maintenance manual for the compressor is adequate. Layout and information presentation for the engine manual were exceptional. Scheduled maintenance was performed according to manufacturer's instructions and found to be adequate, straight-forward and easily accomplished by the operator.

At six hours and forty minutes into the 50 hour test, the compressor was secured to facilitate adjustment of the drive "vee" belts tension. Slack in belt tension was caused by the stretch inherent with new belts. No further adjustment to belt tension was required during remainder of testing. Minor adjustments of the compressor oil pressure regulator were made at hour 22:42 and 46:25. The installed vibration actuated hour meter is not accurate enough to be relied upon.

V. CONCLUSIONS

Evaluation of the BAUER MARINER "D" compressor revealed the following:

A. The BAUER MARINER "D" compressor delivers acceptable breathing air at a charge rate and volume which meets the manufacturer's specifications.

B. The charging cycle time is within manufacturer's specification and is considered to be satisfactory.

C. Fuel consumption of the compressor engine is satisfactory.

D. The unit is sturdy, reliable and readily maintained.

E. The operating and maintenance manuals for both the compressor and diesel engine are adequate.

F. The BAUER MARINER "D" is suitable for use by the U.S. Navy.

TABLE 1

RESULTS OF AIR SAMPLE ANALYSIS

COMPONENT AND CONTENT MEASUREMENT	U.S. NAVY STANDARDS FOR BREATHING AIR QUALITY	COMPRESSOR TEST RESULTS						
		TYPICAL FRESH AIR	HOUR 1	HOUR 5	HOUR 15	HOUR 30	HOUR 45	HOUR 51
OXYGEN %	20-22%	21.0	20.9	20.9	20.9	20.9	20.9	20.9
NITROGEN %								
CARBON MONOXIDE PPM	20 PPM	1.0	2.2	1.4	1.5	2.6	2.1	1.5
METHANE PPM	N/A	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TOTAL GASEOUS HYDROCARBONS AS METHANE, LESS METHANE (T.H.C.) PPM	25 PPM[3]	1.0	5.6	2.7	2.7	1.9	1.9	2.8
CARBON DIOXIDE PPM	1000 PPM	340.0	342.1	331.5	344.3	354.4	366.1	368.4
OIL MIST AND PARTICULATES MG/M^3	5 MG/M^3	0.0	0.2	0.3	LESS THAN 0.2	LESS THAN 0.2	LESS THAN 0.2	LESS THAN 0.2

VI. REFERENCES

1. Task No. 81-12 from NAVSEA 00C-3 to Commander, NEDU, Subject: Test and Evaluate Bauer "Mariner" HP Compressor. (3200 psig/7 ACFM/wt 280 lbs), 27 April 81.

2. NEDU Report 15-80, "Test and Evaluation of BAUER Portable High-Pressure Breathing Air Compressor," Model VARIUS G-3, by R. L. Bowdish, November 1980.

3. NEDU Report 21-78, "Mako High Pressure Breathing Air Compressor," by D. E. Dodds, December 1980.

4. NEDU Report 4-65, "High Pressure Engineering Co., Inc. H.P. Air Compressor 6-CFM Hurricane Model HPE 3000-7-L55," by J.V. Harter, 21 July 1965.

5. NEDU Report 5-60, "Cornelius Company SCUBA Air Compressor Gasoline-Driven, 3.5 CFM," by W. L. Marshall and G. M. Janney, 10 September 1959.

6. Pall Trinity Filter, ANU NAVSEAINST 9597.1 Change 4. Manufacturer installed this filter because of its status as being Authorized for Navy Use.

7. U.S. Navy Diving Manual, Volume 1, Chapter 5, Standards for Diver's Compressed Air.

APPENDIX A

MANUFACTURER'S TECHNICAL SPECIFICATIONS

Model PN 200 bar/3200 psig PN 300 bar/4700 psig	M4D M4DH
Number of cylinders	3
Working process	3-stage
Cylinder bore	88/36/14 mm
Piston stroke	40 mm
Compressor speed	1300 min^{-1}
Intermediate pressure ± 10% PN 200 bar/3200 psig	6/45/225 bar
Intermediate pressure ± 10% PN 300 bar/4700 psig	6.5/47/330 bar
Oil pressure	50 bar
Adjust. of press. maint. valve ± 10% PN 200 bar/3200 psig	150 bar
Adjust. of press. maint. valve ± 10% PN 300 bar/4700 psig	250 bar
Free air delivery[1]) l/min (cfm)	170 (6.0)
Power of motor/engine	4.4 kW (6 HP)
Standard motor/engine	4-stroke Hatz Diesel
Energy consumption/hour	1.7 l diesel fuel
Compressor oil capacity	1600 cm^3 1 qt 16 oz
Oil Summer Winter	above +10°C (50°F) = SAE 30 +10°C to -15°C (50°F to 5°F) - SAE 20 below -15°C (+5°F) = SAE 5 W
Approved oil brands: SHELL ENSIS ENGINE OIL[2]) BP ENERGOL OE-M30 ESSO TRO-MAR T77 Synthetic oils:	MOBIL OIL DELVAC BAUER HP OIL CASTROL MARINE MPX MOBIL RARUS 827 ANDEROL 500

1) measured filling bottle 0 to 200 bar (2900 psig) ±5%
2) no SHELL ENSIS ENGINE OIL permitted which is produced and/or distributed in USA

APPENDIX B

Test Plan No. 81-35, 29 June 1981

1. Program. The test and evaluation of the BAUER MARINER 'D' compressor shall be conducted as follows:

a. Testing to be complete by 31 July 1981.

(1) One compressor will be procured for the initial 50 hour test.

(2) The test director will conduct a delivery inspection to ensure that all components and materials were received in accordance with the manufacturer's specifications and are undamaged.

(3) The test director will inspect for and determine that the following items comply with the requisites of Mariner Technical Manual:

(a) All instruments and controls are clearly marked, legible and precise as to their function.

(b) All controls, gauges and indicators required for safe operation are accessible and convenient to the operator.

(c) Safety devices are present and function as specified in Mariner Technical Manual.

(d) Fluid level indicators accurately display liquid levels.

(e) All removable components shall be removed and properly reinstalled in accordance with the Manufacturers Operating Manual, ensuring correct operation after reinstallation.

(f) Ensure that all drains, traps, safety devices and discharge ports function correctly and are conveniently located and directed away from the operator.

(4) Operate the compressor for one hour under a no-load condition.

(5) On completion of one hour run, take air sample and have it analyzed.

(6) All instrumentation provided by the manufacturer shall be compared with a certified true source and an accuracy data sheet produced for the report.

(7) Conduct 50 hours of testing with procedures set forth in Section 3.

2. Preliminary Arrangements

a. Arrange for air sample analysis to be conducted within 72 hours of samples being drawn from the compressor.

b. Arrange for a gauge calibration facility to compare all the instrumentation before and after test cycle.

3. Test Procedure. The following test procedures will be conducted as specified and the results entered in the evaluation log:

a. Air samples shall be taken at hours 1, 15, 35, 50 and anytime the air quality is questioned or major defects occur.

b. The following shall be logged during all operations:

(1) The time and date.

(2) Start-up time.

(3) Securing time.

(4) Filter pressure.

(5) Size and rated pressure of flask(s) being discharged into.

(6) Total running time, hrs/min.

(7) Ambient air temperature.

(8) Delivery air temperature.

(9) Volume of condensates.

(10) Relative humidity.

(11) Fuel consumption.

(12) Crankcase oil consumption in prime mover and compressor.

c. Compute the discharge volume of the compressor by filling a known container to 3000 psig. This shall be completed and logged at least every three hours of running.

d. Measure the fuel consumption and compute the rate at least three times during the test and record the findings in the log.

e. Oil consumption shall be measured and recorded in the log.

f. Perform all maintenance as specified in the Manufacturer's Operation Manual.

4. Safety Rules and Precautions. Safety rules and precautions as outlined in Manufacturer's Operators Manual and those of the U.S. Navy shall be observed throughout the evaluation.

5. Comments/Additional Information. NEDU Test and Evaluation Department has the responsibility to ensure that the following parameters are met. The department or its representative, has the prerogative of terminating all testing anytime that one of the following parameters is not achieved.

a. Control and Safety of Systems. All control systems, safety systems, and valves shall be activated by making the necessary temporary alterations to the compressor controls and operations whenever such alterations will not result in a risk of damage to the compressor unit. Where a risk is present, the test may be conducted with control systems completely removed from the compressor unit by subjecting control system sensors to external test sources of temperature and pressure.

b. Integrity of the Air System. The air compressor system shall be shut down when the system is at max pressure and the following process shall be accomplished.

(1) Hold pressure.

(2) Allow the system to cool to ambient temperature.

(3) Record the receiver pressure.

(4) Let it set sealed for an eight hour period and record the pressure again.

(5) The leak rate should be zero.

c. The following is the criteria for failure and termination of testing for the BAUER MARINER 'D' compressor.

(1) Failure of any component which cannot be corrected in accordance with operators or technical manual.

(2) Failure of the air system to operate as specified by the manufacturer.

(3) Failure of any valve to operate properly.

(4) Failure of any pressure relief device to operate as specified.

(5) A decrease in capacity of the compressor or during the performance test.

(6) A discharge air temperature in excess of the manufacturer's specifications.

(7) Failure of any air sample to pass the breathing air specifications set forth in U.S. Navy Diving Manual Volume 1.

APPENDIX C

SAMPLE BAUER MARINER TEST LOG

DATE: 28 JUNE 1982

TIME	HOURS	DISC PRESS	AMB TEMP	DISC TEMP	REL HUMID	VOL DRAIN	REMARKS
1010	22:46	1100	32.9 C	33.0 C	74%		STARTED COMPRESSOR FOR 1 HOUR NO LOAD.
1018							STOPPED COMPRESSOR FOR 2 MINUTES & TIGHTENED LEAKING FITTINGS.
	23:08		36.0 C	63.0 C	65%	40 ML	DRAINED CONDENSATE.
	23:28		34.0 C	37.0 C	68%	70 ML	DRAINED CONDENSATE.
	23:42						ADJUSTED COMPRESSOR OIL PRESSURE.
	23:50		35.0 C	39.0 C	68%	80 ML	DRAINED CONDENSATE.
1114	0:00		36.0 C		67%		COMMENCED 50 HOUR TEST.
	23:58		35.0 C	38.0 C	68%	50 ML	GAS TANK CAP LEAKS AND BOLTS VIBRATED LOOSE.
1126	0:00		36.0 C	38.0 C	67%		STARTED FILLING TWIN 50 SCUBA BOTTLE.
1141	0:27						FILLED TWIN 50'S LOW, HOUR METER QUIT AT 23::57.
1143	0:29		36.6 C	38.1 C	65%	60 ML	DRAINED CONDENSATES.
1159	0:40		36.6 C	38.0 C	66%	45 ML	CHANGED 50'S 13::10.
1200	0:46						RESET CLOCKS.
1207	1:10		37.3 C	39.9 C	62%	50 ML	CHANGED 50'S 13:00.
1224			35.7 C	39.3 C	63%	60 ML	CHANGED 50'S 17:00 3RD STAGE PSI 4.000.
1238	1:24	3000					CHANGED 50'S 14 MIN.

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